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INTEGRATING LIVESTOCK INTO FARMING SYSTEMS IN NORTHERN CAMEROON*

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ABSTRACT

Farming systems in West Africa's semi-arid zone consist of mainly purely nomadic pastoralism and purely sedentary crop production with a minor crop-livestock production system. Farmers there are slow to integrate cropping and livestock and utilize their intermediate farm products of crop residues, draught power and animal manure to tackle the production constraints such as shortage of animal feed, labor bottlenecks, and soil degradation. This paper uses a crop-livestock linear programming model to show that, apart from the adoption of crop technologies, by integrating and using crop-livestock farm linkages, farmers can make more efficient use of their marginal land with less chemical fertilizers, improve their economic gains substantially, and achieve a more sustainable agricultural production system.

Keywords:

Integration of crop-livestock, linear programming, linkages of farm activities, utilization, profitability, intermediate farm products, technology adoption, semi-arid zone

1. INTRODUCTION

Livestock and crop farm systems are major components of agricultural production in the semi-arid zone of West Africa[1]. Nevertheless, the two farm systems have not yet been well-integrated so that the livestock farm system can benefit the crops as a source of draught power, not only for plowing[2], but also for planting, weeding[3] and transportation as well as providing animal manure to replenish badly-needed soil nitrogen and organic matter[4,5]. In addition to the benefits livestock provide to the cropping system, crops could provide grain and crop residues as sources of animal feed, especially during the dry season.

Instead, in the Sahelian region, with less than 600 mm of rainfall, a purely nomadic pastoral system prevails at a high stocking rate of over 17 tropical livestock units per hectare[6]. Meanwhile, the Sudano-Guinean region with 600-1000 mm of rainfall is dominated by crop cultivation. There is also a minor mixed crop-livestock farm system where semi-nomadic[7] or sedentary livestock farmers cannot afford to maintain their animals through the dry season, but have to entrust them to nomadic herdsmen due to a shortage of forage[8].

In the case of Northern Cameroon, our study area, the nomadic pastoralists who keep 30 to 200 head of cattle originally lived in the Extreme North Province. But during the dry season in the months of January through April, most of the scanty vegetation in the Sahelian zone becomes desiccated and the standing hay is often completely destroyed by animals and bush burning. During this period, the nomadic herdsmen migrate southward in search of grazing grounds, thus causing social conflicts with the sedentary crop farmers. Moreover, the large inflow of livestock and/or introduction of more livestock on crop farms in this region without appropriate integration can create competition for farm resources such as land, labor and farm cash. This paper argues that when crop and livestock production are integrated and their activities synchronized, then the two farm systems can generate complementary relationships without competition for farm resources.

1.1 Objectives

The objectives of this paper are:

1. To identify the benefits of a crop-livestock mixed production system that emphasizes the complementarities of integrating the two major components into one farming system.
2. To formulate a feed management regime that mixed farmers in Northern Cameroon can use to maintain 2 to 20 cows on their farm throughout the year.
3. To demonstrate the profitability of mixed farming and the sustainability of agricultural production by integrating livestock into the present crop-based farming system.

1.2 Cropping Systems

The main traditional food crops in Northern Cameroon are sorghum, millet, maize, and cowpeas. Red sorghum is grown by 85% of all farmers, cotton by 78%, groundnut by 73%, and maize by 60%. Cotton, a dominant cash crop, is planted on the largest percentage of land (36%), followed by red sorghum (25%), groundnut (14%) and maize (13%). Groundnut is both a food and a cash crop[9].

The main crop associations on farmers' fields include red sorghum-white sorghum (grown by 56% of the farmers), sorghum-cowpea (38%), groundnut-sorghum (25%), and groundnut-sorghum-maize (18%). The average farm size per family in the study area is 3.37 ha, but 70% of the farmers have farms of 0.25-2.00 ha. Farmers usually partition their farms into small plots (0.25 ha) and all crops (except cotton) are grown on less than 1 ha.

The cropping calendar varies with the length of the agricultural season (4- 6 months). In the West Benoue region, farmers tend to plant in the last 10 days of May. However in other regions, farmers stagger their planting from late May to early July in order to minimize the effect of intermittent rains. In any case, sorghum is the first crop to be planted, followed by groundnut.

The most common land clearing method is slash and burn, especially for maize, cotton, and groundnut which are more susceptible to weed infestation. Light clearing is used for other crops. Most farmers use an ox plow to prepare the soil for the cultivation of maize, cotton, and groundnut (75%), but less so for sorghum, cowpea, and muskwari, where they use a hoe for soil preparation. From 58 to 71% of the farmers plant cotton, maize and groundnut in rows, while only 6 to 23% plant cowpea and sorghum in rows. All weeding is done with a hoe and no herbicides are used. At the first weeding, more than half of the farmers make small mounds around the plant and make ridges 30 to 40 days after planting to conserve moisture. Very few farmers use draught power for making ridges in the cotton field. Hardly any farmer uses draught power in weeding and transportation.

The soils are mostly sandy loam and very poor in organic matter, total nitrogen and potassium. Farmers who grow cotton may obtain fertilizer on credit from a parastatal (SODECOTON) and repay at harvest with cotton. Two-thirds of them use fertilizer on cotton and some apply cotton fertilizers to maize (40%) and to groundnut (10%). No chemical fertilizer is applied on traditional food crops and few farmers use organic fertilizers[10].

1.3 Livestock Systems

Livestock production is an important component of the agricultural sector in Northern Cameroon. The country has a land mass of 46.944 million ha, of which 6.3% is under crop production, 36.5% under livestock, 42.1% under forest and 14.8% under water[11]. Out of the country's total of 3.512 million cattle, 1.512 million sheep, 1.904 million goats and 0.04 million horses and donkeys, Northern Cameroon carries 78% cattle, 61% sheep, 53% goats and 100% of the draught power animals, plus 28% of the 11 million people[12] on 22% of the total land. The nomadic Fulbe herdsmen keep an average of 5 head of cattle per farm family and most of the goats and sheep. The sedentary crop farmers own 1 to 4 bullocks per farm family and use them mostly for ox-plowing. But as indicated elsewhere, the sedentary livestock system is constrained by a shortage of feed during the dry season, coupled with the lack of water and veterinary services.

1.4 Livestock-Crop Relationship

The relationship between livestock and crops could be competitive or complementary depending on the level of coordination of resource use such as land, labor or capital[13]. In West Africa, it may depend on the central national policy issues such as (a) reforestation, (b) degradation of pasture and/or (c) demand for the same land by agronomy, animal husbandry and increased population pressure[14,15].

The semi-arid zone has a high population density of 20 to 45 persons per km^2 [16]. It also contains numerous animals with a stocking rate of 425 kg/ha[17], which is about 2%, 15% and 50% higher than the carrying capacity of the best land types F_1, F_2 and F_3 found in the depressions having 30% bush cover[18]. At the same time, the national policy is to get ONAREF (National Office for Regeneration of Forests) to maintain 20% of the national land under forest[19]. This situation reduces land available for pasture and crop cultivation, thus creating competition between crops, animals, forestry and human population for space.

Although most sedentary livestock farmers entrust their animals to Fulbe in the dry season, some have learned to exploit the complementary roles of livestock and crop farm systems. A few of these farmers have participated in trials to evaluate the feasibility of keeping their draught animals on the farm during the dry season and grazing them on stubble after harvest. They have also learned to supplement their sources of animal feed in the dry season with crop residues of groundnut and cowpeas, as well as fodder from trees such as *Khaya senegalis*, *Acacia albida*, plus purchases of cotton cake for those who can afford it[20]. Animal traction ownership had increased among farmers growing cotton (a cash crop) and those who had access to credit facilities from SODECOTON (a cotton corporation), FONADER (Fund for Agricultural Development) and NEB (Northeast Benoue Project) before the credit facilities were cut off in 1989.

2. METHODS AND SOURCES OF DATA

The data used in this model were collected from Northern Cameroon by the SAFGRAD/FSR project from 1986 through 1988. Using a whole-farm systems approach, the project carried out, among other things, surveys of farm labor, prices, and traditional livestock and crop production practices. The SAFGRAD/FSR team, in collaboration with the Institute of Animal Research, also conducted on-farm trials on various ways of integrating livestock into the farming systems. The FSR team carried out a number of experiments such as the use of animal manure alone or in combination with chemical fertilizers and use of draught power for plowing, harrowing, ridging, weeding and transportation. Trials on using crop residues of cowpeas, groundnut, maize, and sorghum to feed draught animals were carried out in 1987 and 1988 with a sample of 42 mixed farmers.

The sampling of farmers was through a multi-stage random sampling procedure. The study area was subdivided into agro-ecological zones, namely the Sahel, Sudan and Guinea savanna zones. Each of these were in turn subdivided into regions and then recommendation domains according to certain criteria regarding cropping, soil types and farmers' socio-economic setting. A list of villages in each region was then compiled and two to three primary villages were randomly selected. A comprehensive list of farmers in the selected villages was compiled, from which five to 10 farmers were randomly selected. After this, smaller samples were selected for specific surveys and field trials.

For data collection, seven field assistants were deployed to reside and work in the primary villages. Each field assistant was equipped with questionnaire forms, a spring balance, a record book, and other materials, as well as a motorcycle for transport around the villages. Under supervision, each field assistant made the rounds at regular intervals to note observations and collect data. The frequency of visits to farmers was such that farm labor, draught power and animal feed consumption data were collected every two days, price data were collected weekly, and use of manure was recorded at plowing and planting. Agronomic observations of soil fertility maintenance and tillage methods were made at soil preparation, seeding rate at planting, crop husbandry and crop growth at weeding, plus grain and residue yields at harvest. Details on farm labor were recorded including: how many workers were from the family or hired, the sex and age of the workers, the crop and type of farm operation on which they worked, and the length of the working day. Details of animal husbandry including nutrition (both from grazing and other feeding) and use of draught power, as well as the labor required for collecting and transporting manure to the field, were also recorded.

3. THE REPRESENTATIVE FARM MODEL

Preliminary analysis of modifications to farm production choices often takes the form of budgeting. Budgets for the improvements to cropping technology considered here (e.g., improved varieties, introduction of cowpea) and for the integration of livestock and crop production indicated net improvements in returns to fixed resources. However, budgeting analysis does not permit the allocation of value to the individual factors of production. Neither does it permit the identification of resource scheduling bottlenecks. Thus, for the second stage of analysis we use linear programming for a representative farm planning model[21].

Our primary focus in this investigation is on the relatively resource-poor, small, crop farmer. The model of integrating livestock into the farming systems of Northern Cameroon has three main features. First are the activities related to the livestock subsector; second, the activities related to the crop production subsector; and thirdly, a dynamic interrelationship between activities and constraints linking the two subsectors, thus treating the whole-farm as a single system for livestock and crop production. The model has 200 choice variables and 130 constraints. The farmer's objective function to be maximized is profit subject to subsistence constraints. The model (model solutions are interpreted as a steady state equilibrium) selects the most profitable mix of livestock and crop activities subject to the constraints of the farm system. The activities in the livestock subsector can be grouped into six categories. These range from rearing, grazing, buying and selling livestock activities to various sources of animal feed per period. The activities in the crop production subsector can be grouped into eight categories, ranging from growing and selling crop activities to on-farm consumption and supply of farm inputs (see Figure 1).

3.1 Farm Land

As indicated elsewhere, the farming systems in Northern Cameroon consist of three types of crop/livestock farmers. These are crop farmers, purely nomadic pastoralists and crop-livestock (mixed) farmers. The nomadic pastoralist farmer owns an average of 50 cows and 30 goats and sheep per family. The mixed crop-livestock farmer owns an average of 4 cows and 9 goats and sheep, while the crop farmer does not keep livestock and grows only crops with farm sizes of 1 to 4 ha and has a farm annual income of about $1000.

Farmers obtain their land by inheritance. Although the population density in Northern Cameroon is below the national average of 21 persons per km^2 [22], the Diamare, Margui-Wandala and Danay areas of the Extreme North Province have relatively high population densities of over 60 persons per km^2. Moreover, more than 50% of the land area, particularly the Mandara highlands and in the older settlements, has been badly degraded by soil erosion due to torrential rains and winds, as well as human and livestock activities. Most soils in the Extreme North Province and in Mayo Luti of the North Province have become extremely poor, sandy hardpans or even bare rocks[23].

Survey results by the SAFGRAD/FSR/Cameroon project, whose data were used to determine the land endowments of the representative farm, show that on the average, a farm family has access to 16.21 ha of land, of which 6.21 ha is under crop cultivation and 10 is under fallow. The farmer's land holding can be classified according to soil fertility levels into medium level fertility (55% of the land), low level fertility (26%) and sandy poor (14%) or hardpan poor soils (5% of the land)[24,25]. Thus, the farmer's land resource can be classified into F_1, F_2, F_3 and F_4 types of land according to their fertility levels. Usually farmers can tell how fertile the soil is by its color and coarseness. The average area of the F_1 land is 3.1 ha. This land has black or grayish soils, and is good for growing maize and cotton. The F_2 land area averages 1.46 ha per farmer. This land has grayish-yellow soils which can maintain sorghum or groundnut, but would need a high dose of fertilizer in order to grow maize. The F_3 land covers 0.9 ha per farm on average and has sandy-loam soils with very poor fertility levels that are only suitable for cowpeas. The F_4 land covers an average of 0.75 ha and consists of vertisols which are black clayey soils and are water-logged during the rainy season. It is only good for transplanted sorghum ("muskwari"), which grows on residue moisture during the dry season.

3.2 Farm Labor

Although the family sizes in the extreme north of Cameroon are large with 9 to 10 persons per family, the average size of a farm family in the study area is 5 persons. The family composition consists of a man, a woman, two children ages 10 to 18 years and one child under 10 years. The sources of farm labor are family and hired labor. The average family labor available is 2.75 man-units, considering that a man is 1 unit, a woman 0.75 units and two children 0.5 units each for ages 10 to 18 years. Family labor may be supplemented by the use of hired labor with wage rates varying according to seasonal averages.

Since Northern Cameroon has a unimodal rainfall starting in April/May and cutting off in October, the cropping calendar is such that farmers plant in May/June and harvest in October/November. The months of January to April are dry and hot, only certain field operations, such as bush clearing in April or cotton picking in January and February, can be done in the early hours of the morning when temperatures are still favorable. Besides, performing farm operations in April depends on the onset of the rains. For the rest of the periods in the cropping calendar, family labor supply is according to the number of available working days (see Table 1).

3.3 Sources of Animal Feed

The livestock farmers in Northern Cameroon and elsewhere in the semi-arid zone of West Africa usually feed their animals by grazing them on natural pasture. However, during the dry season, most of the vegetation becomes desiccated and is often burned down by bush fires. The crop farmers leave crop residues on the field, which usually are grazed by animals and/or consumed by termites early in the dry season. So in the months of March, April and early May before the new season, there is a serious shortage of animal feed in the area. Our strategy for the integration of livestock and crop production included in the model is to collect and store these crop residues for use in stall feeding during the months of shortage. Labor requirements are reflected in these storage activities.

It has been noted that maize, cowpea and groundnut dry stalks are good sources of animal feed on a forage basis for cattle, goats, and sheep because they contain 80 to 90% dry matter and 50 to 59% digestible nutrients[26,27]. The cowpea and groundnut dry stalks are also rich sources of crude protein (10 to 20%), of calcium (1.2%), of phosphorous (0.15 to 0.35%), and contain 14 (1000 international) units of vitamin A. Other optional sources of feed used in this model are grasses such as *panicum maximum*, pennistrum, leguminous shrubs, bran of grain husks and cotton cake. The coefficients for the dry matter and crude protein content were calculated from data collected in Northern Cameroon, while the coefficients for calcium, phosphorous and vitamins were obtained from published data[28,29,30].

3.4 Farm Cash Income

Farmers in Northern Cameroon obtain their cash earnings by selling their crops or livestock, or by performing off-farm activities such as small trading, handcrafts and renting out their labor services for constructing buildings, etc. Cotton is a cash crop and a foreign exchange earner for the economy. Groundnut serves a dual purpose of cash and food crop. As indicated elsewhere, the traditional crops are sorghum, millet, and groundnuts, but maize and cowpeas (which are relative newcomers) seem to have a potentially favorable market. Most of the farmers using traditional cultural practices earn about $1000 a year. The medium-size farmers who may adopt some of the modern crop and/or livestock technologies earn around $5000 a year. These farmers are considered progressive by extension agents. There are very few farmers who earn over $5000 a year. Therefore, farmers face serious cash constraints. Credit facilities are hard to come by. The two possible credit facilities, FONADER (Funds for Agricultural Development) and SODECOTON (a cotton corporation) which provide credit for the purchase of cotton fertilizer and insecticide are no longer in existence due to a national austerity plan. So in this analysis, we shall consider two types of farmers: a small crop or mixed farmer with an average initial cash of $1000 and a medium-size crop or mixed farmer with initial cash of $5000.

3.5 Crop Activities

The crop activities in this model are: growing crops, selling farm produce, subsistence consumption, and purchasing inputs like draught power and fertilizer. Crop growing activities include traditional crops and improved varieties of maize (T7PB and CM8501), cowpea (Vya), white sorghum (S35 and SC95) and groundnut (28206 and Kl 77-441). The crop growing activities of these traditional and improved crops are the various planting dates, namely May 10, May 30, June 10 and June 20. The improved crop varieties also have June 30 and July 10 as the additional planting dates. Crops are sold for cash at harvest. The farm family subsistence minimum consumption levels are 500 kg of maize, plus 200, 150 and 150 kg of cowpeas, red sorghum and white sorghum, respectively. There are draught power hiring activities with costs based on average rates corresponding to each of the 11 periods in the cropping calendar (see Table 1). We also have buying activities for compound NPK 20-10-10, urea and superphosphate fertilizers.

3.6 Livestock Activities

The principal livestock activities are cattle rearing, small ruminant rearing, buying and selling animals. Other livestock activities include grazing and feeding the animals on crop residues or other supplementary feeds per livestock period.

In this model the mixed farmer has an initial stock of 2 cows and no goats. He can increase his livestock by buying additional animals, and receives revenue from livestock sales at year end. Since this is a steady state equilibrium model, the optimal solution then indicates the number of animals that should be kept each year. A negative coefficient on the livestock activity in the objective function represents the cash demand to cover the costs for veterinary services.

In accord with the nutritional requirements of livestock, an average cow of 286 kg of live body weight requires 6.365 kg of dry matter per day, of which 3.61 kg must be total digestible nutrients (NAS, 1981). The nutritional daily intake of the cow should also include sources of crude protein, phosphorous, calcium, cobalt, trace minerals and vitamins A, B, D, E and K. A goat or sheep with an average live body weight of 60 kg requires a daily intake of 1.718 kg dry matter, of which 0.955 kg must be digestible nutrients (TDN), as well as a sufficient supply of the other nutrients[31].

Regarding maintenance of the animals, livestock have to be cared for during both the rainy and dry seasons. This model considers a 12-month livestock calendar divided into nine periods (Table 1, columns 5, 6 and 7) in order to coordinate with the cropping calendar. In addition, provisions have been made to fulfill labor demands for stall feeding the animals in the mornings and evenings, plus grazing for each day throughout the livestock calendar. Some labor has also been allowed for gathering, carrying and storing animal feed. There is also labor needed to train the draught bullocks, as well as to control them when actually at work in the fields. The draught resource use in this study is based on hours of draught power supplied by one bullock per crop period (Table 1, column 4).

3.7 Livestock-Crop Linkage Activities

The model contains six linkage activities of livestock and crop production systems, with dynamic interrelationships and interactions between the livestock and crop submodels. The six built-in linkages are: sources and uses of (1) animal feed, (2) draught power, (3) fertilizer (i.e., manure), and uses of (4) land, (5) labor and (6) cash (see Figure 1). In this model of crop-livestock integration, the crop subsector provides crop residues to the livestock as sources of animal feed. However, the livestock-crop (mixed) farmers can supplement crop residues with purchases of cotton cake in periods 1 to 5 (the dry season), grazing green pastures in periods 6 to 7, grazing stubble left on crop fields during periods 8 to 9, and with hay made out of grasses harvested from fodder banks[32]. The model also permits the farmer to purchase additional salt, cobalt, vitamins, and other minerals.

In the livestock subsector of the model, demands by animals for nutrients such as dry matter, digestible energy, crude protein, vitamins and minerals are supplied from the various feed sources for each of the nine livestock periods. Crop residues and hay from fodder banks[33] are harvested at the end of October (periods 8 and 9) and stored to be fed to the animals as needed in each of the nine periods.

In this integrated farm systems model, the livestock subsector adds benefits to crop production by providing animal manure to enrich the poor soils and draught power to alleviate the severe shortage of farm labor for the operations of soil preparation, weeding and transportation. It has been suggested that the limited use of animal traction in the semi-arid zone of West Africa in general, and Northern Cameroon in particular, is due to the high opportunity costs of maintaining the animals at the farm during the dry season[34,35]. However, there are indications that if the animals are kept on the farm, they can provide manure for the crops and if fed on farm-produced forages, then problems of shortage of feed would not arise[36,37]. Thus, integrating livestock and crops in this model illustrates how the sedentary crop farmers can maintain their animals and have them available for the first plowing at the onset of rains in early May. Thus, they can eliminate delays in plowing operations and the need to entrust their animals to nomadic herdsmen during the dry seasons.

Four cows can produce sufficient manure to fertilize 1 ha. Manure may be applied to a piece of land once every two years and 5 t/ha of animal manure can supply 100 kg N, 17.5 kg P and 50 kg K[38,39]. This needs to be supplemented by one-quarter dose (1 dose = 90 kg) of chemical N fertilizers per hectare because manure decomposes at a slow rate and approximately 18% and 33% of the manure N and P is assimilated by the first nonleguminous crop[40]. If livestock and crop production activities are not well synchronized, they can compete for labor, land and farm cash constraints. In the model, both livestock and crop production compete for labor and land resources by period. Time periods are coordinated between these submodels according to the schedule in Table 1 and Figure 1.

3.8 The Preharvest Cash Constraint

The bulk of fertilizer sales is handled through the parastatal SODECOTON. In order to qualify for fertilizer purchases, a farmer must agree to pay for the fertilizer with cotton. Thus, to reflect this restriction on farm input purchases, a constraint is included to force fertilizer purchases to be less than or equal to cotton revenues.

Northern Cameroon has favorable climatic conditions in terms of sunshine and rainfall for the grain production of maize, cowpeas, groundnuts and sorghum. However, it is at the same time the sole region producing cotton in the country. Although the area planted to cotton in thousand hectares has increased from 73 in 1984 to 94 in 1988, SODECOTON, a parastatal for the promotion of cotton production and rural development, suffered losses in the tens of millions of dollars in 1985, 1986 and 1987[41]. Thus while the French development and investment corporations like FAC and CIRAD plus the national government, desire to diversify Cameroonian exports via developing the export market for maize, an alternative version of this constraint is also considered. In the alternative constraint for a maize and cotton-based economy, fertilizer purchases are restricted to be no more than the sum of cotton and maize revenues.

3.9 Validation of the Model

In order to assess the degree to which the model reflects farmer's choices, it is necessary to validate our model against survey data from North Cameroon. Here, the model validation process involved comparing the model results with the reported actual values of land use and livestock owned. During the validation runs, the model was structured according to similar farmer conditions prevailing in the area of study, i.e., using traditional crops and cultural practices. Table 2 shows the values of gross margin, animals kept and crops grown by crop or mixed farmers. In Table 2, the model validation results are compared to the values obtained from farm surveys. According to the survey results of crop and livestock production systems in Northern Cameroon, most farmers use traditional crops and cultural practices. An average crop farmer earns approximately $1000, has a family size of five persons and cultivates a total of 2.553 ha, of which 23% is maize, 19.6% red sorghum, 13% groundnut, and 11% cotton. The traditional crop farmer may grow muskwari if he has water-logged vertisols found in the bottom land.

The results obtained from the validation run for a crop farmer in Table 2, column 4, are similar to those from the survey. For instance, the gross margin of $1180 from the validation run is not very different from that of $998 from farm surveys. In the model validation results for a crop farmer, maize still ranks first and groundnut still ranks third as in the survey results; however, cowpeas rank second at 26.5% of the land replacing red sorghum. This is partly because cowpea is the most recently introduced crop in the area and not many farmers had adopted it during the survey period (1986). During this period farmers tended to leave F_3 land fallow because it has very poor soils that can only maintain cowpeas. Since the model does not attribute direct benefits to fallow and since adequate resources are available, all F_3 land is planted to cowpeas. The model, however, increases land under white sorghum and selects to use all available vertisol, F_4 land for transplant sorghum (muskwari), but maintains the land planted to cotton at about the same level. Except for these relatively minor differences, the model replicates the choices of a crop farmers fairly accurately.

A similar validation exercise was performed for a mixed farmer. Again, a validation run was made with similar conditions as those of a traditional mixed farmer in Northern Cameroon. That is, the farm is restricted to cultivating traditional crops and keeping a small number of livestock, mainly for draught power and emergency cash, but without the linkages of using animal manure for fertilization or crop residues for animal feed. Table 2 shows the gross margins, numbers of livestock kept and crops grown for a mixed farmer as obtained from the validation run. The average mixed farmer from the survey results (Table 2) keeps 4 cows, 9 goats and maintains a farm size of 5.14 ha. In the validation run, the model selected to keep the same number of goats at 9, but reduced the number of cows to 2 and increased the farm size to 7.38 ha. The reduction in number of cows reflects the difficulty of maintaining the animals during the dry season as no provision was made for entrusting animals to the nomadic herdsmen during this period. Regarding the allocation of land to the crops grown, the traditional mixed farmer plants the largest part of his land to cotton, followed by traditional crops of red sorghum, groundnut, maize and white sorghum. But in the validation run, the model selected to allocate the largest part of the land to maize, followed by cotton and cowpeas. Thus, apart from maize and cowpeas which are relatively new crops, the order of the traditional crops in the validation run for the mixed farmer is similar to that from the survey data.

4.0 RESULTS AND DISCUSSION

As indicated elsewhere, this paper considers farmers with and without livestock in a cotton-based or maize-based rural economy. The results of the model are presented in Tables 3, 4 and 5. We shall now discuss these results with policy implications, one by one.

4.1 Contributions from Improved Crop Technologies

In order to assess the contributions of improved crop technologies, we shall compare the profitability, resource productivity and choice of improved crop varieties in the model results of farmers without livestock (Table 3) with those of farmers growing traditional crops (Table 2). First, under a cotton-based system, a small or medium size farmer without livestock but with improved crop technologies (Table 3, columns 2 and 3) has a gross margin of $1368 or $2608 which is 15.93% or 121% higher than that of $1180 for a small farmer (Table 2) with traditional crops; or 37.1% to 161.3% higher than $998 obtained from the survey data. By considering, for instance, returns to land, gross margin divided by farm size, the farmer with traditional crops in Table 2 earns $346 per hectare. But with improved crop technologies farmers can make some increases in their resource productivity. A small farmer obtains $353 per hectare of land, thus increasing his land productivity by 2%. Whereas a medium-size farmer with improved crop technologies can choose to double his farm size and increase his land productivity by 3%. However, the most notable contribution from the introduction of improved crop technologies is the choice of crop activities selected by the model. Apart from the small farmer under a cotton-based system who chose to plant all his cowpea land to traditional varieties, both the small and medium size farmers selected to plant all their respective individual crop land to improved crop varieties of maize CMS8501, white sorghum S35, cowpeas Vya and groundnut Kl 77-441. Regarding the proportion of land resource allocation to various crops under the cotton-based system for the small farmer, the model selected to allocate the largest part of the land to groundnut (1.0 ha, 26%), followed by cowpeas (0.9 ha, 23.8%), maize (0.8357 ha, 21.5%) and muskwari (0.75 ha, 19.3%). For the medium size farmer, the selected crop activities are first maize (2.8921 h, 39.4%), followed by cotton (1.3342 ha, 18.2%), groundnut (1.0 ha, 13.6%), cowpeas (6.9 ha, 12.3%), then muskwari in fifth position at 0.75 ha or 10.2%. These results suggest that the improved crop varieties can increase the farmer's profitability and resource productivity, and are adaptable to the farming conditions.

4.2 Contributions from Improved Crop Technologies and Integration of Crop-Livestock

Optimal levels for gross margin, livestock kept and the crop area grown for crop-livestock (mixed) farmers with access to improved crop technologies are displayed in Table 3. These results can be attributed to two sources of improvements. First, there are the contributions accruing from the introduction of improved crop technologies and, second, those arising from the integration of crop with livestock.

Thus, a small crop-livestock farmer adopting improved crop technologies may obtain a gross margin of $5226 under a cotton-based system or $5563 with the maize-based system. Then a medium-size mixed farmer can obtain a gross margin of $7299 under a cotton-based economy. This indicates that a small mixed farmer that chooses to adopt improved crop technologies can raise his income by 7% higher than the mixed farmer growing traditional crops. A medium-size mixed farmer can increase his farm income by 49% from adopting improved crop technologies.

On the other hand, there are the contributions from integrating crop with livestock. The results in Table 3 show that a small mixed farmer can profitably maintain 2 cattle and 1 goat, and a medium-size mixed farmer can maintain up to 11 cattle and no goat under a cotton-based economy.

A comparison between columns 2 and 4 or columns 3 and 5 in Table 3 indicates that a small farmer who has already adopted improved crop technologies can increase his gross margin by $3858 (282%), and a medium-size farmer can increase his gross margin by $4691 (180%) under a cotton-based economy from the integration of crop-livestock farm systems.

Now considering the farm sizes of the crop for mixed farmers in Table 3 together with their respective gross margins gives economic returns to land per hectare of $747.53 and $803.15 for a mixed small and medium-size farmer, respectively, under a cotton-based economy.

Regarding the allocation of land to various crops grown by the mixed farmers, Table 3, shows that a small farmer under a cotton-based economy selects to plant the largest part of his land to maize (2.55 ha, 36.5%) followed by white sorghum (1.3773 ha, 19.7%), cowpeas (0.9 ha, 13%), cotton (0.759 ha, 11%) and muskwari (0.75 ha, 11%). Then the medium-size farmer under a cotton-based economy also selected maize at 4.734 ha (52%) as the most important crop, followed by cotton (1.2408 ha, 13.6%), cowpeas (0.9 ha, 10%) and muskwari (0.75 ha, 8.2%). The model selected to plant improved crop varieties of the leading crops, thus suggesting that the improved crop varieties of maize CMS8501, cowpea Vya, white sorghum S35 and groundnut 28206, which have dual purposes of high grain yield and good quality and quantity of crop residues, fit very well in the crop-livestock integrated farming system. This implies that the integration of crop and livestock production can improve land productivity by 95% ($375.33/ha) to 112% ($394.53/ha) for the small mixed farmer and by 106% ($354.14/ha) to 126% ($447.64/ha) for the medium-size mixed farmer under maize and cotton-based economy, respectively.

4.3 Complementarities and sustainability from crop-livestock integration

As indicated in section 3.7 and Figure 1, this model has six built-in crop-livestock farm linkages. Each of its optimal solutions ensures: 1) selection of profitable crop and livestock activities, 2) efficient use of intermediate products and 3) complementarities between the two farm systems.

Table 4 shows the use of intermediate farm products and farm inputs in the optimal solution of the crop-livestock integration model of Northern Cameroon. In the case of a small farmer under a cotton-based economy, for instance, the crop subsector can provide in metric tons of dry crop residues 1.978 groundnut stalks, 2.226 sorghum stover, 2.7 cowpea stalks, 12.749 maize stover and 4.625 hay from grass to feed two cows and one goat throughout the nine livestock periods. Whereas, a medium-size farmer can produce in metric tons of dry crop residues 2.371 groundnut stalks, 1.193 sorghum stover, 2.7 cowpea stalks, 23.669 maize stover and 17.189 hay from his crop enterprises to feed and maintain 11 cows on his farm throughout the year. Under a maize-based economy, apart from increasing the use of maize stover by 25% to 75%, both the small and medium-size mixed farmers use the same proportion of crop residues as sources of animal feed. Another significant outcome from the integration of farm systems is that the owned livestock can provide to the crop production system draught power and animal manure. According to Table 4, under a cotton-based economy, the small mixed farmer utilizes 168.44, 121.11 and 77.11 total hours of owned draught power for plowing, weeding/ridging, and transportation, respectively. The medium-size mixed farmer used 228.02, 187.58 and 95.93 hours of his owned draught power on similar farm operations for all his crops. Whereas under a maize-based economy, the small mixed farmer used 175.82, 120.73 and 78.87 total hours of owned draught power on plowing, weeding/ridging and transportation. The medium-size mixed farmer used 286.41, 260.41 and 109.92 total hours of owned draught power for the same farm operations. Under the maize-based economy, the farmers used more of their owned draught power partly because their farm sizes are 3.4 to 27.34 percent larger and because of having a greater part of the land planted in maize, a crop that is most adaptable to use of draught power.

The importance of the intermediate farm product of animal manure to revitalize the degraded soils and to maintain soil fertility in Northern Cameroon cannot be over-emphasized. A small mixed farmer has

4.03 or 4.46 MT of dry animal manure available for use under a cotton-based or maize-based economy. This is equivalent to around 80, 14.1 and 40 kg of nitrogen, phosphorous and potassium, respectively. Of course, application of animal manure on cropland will also increase the organic matter content in the soil[42]. Moreover, the integration of crop and livestock production results in a more efficient use of marginal and fallow land. For instance, a small mixed farmer converts 0.771 ha from fallow into F_1 and F_2 cropland under a cotton-based economy or 1.01 ha under a maize-based economy with the application of manure and chemical fertilizers. The medium-size mixed farmer can convert from fallow into F_1 and F_2 cropland 2.8646 ha under a cotton-based economy or 5.35 ha under a maize-based economy.

Table 5 shows the land schedule for grazing the animals throughout the livestock and cropping calendars. The figures in Table 5 represent the number of hectares of the respective class of land being used for grazing in each period. According to Table 5, a small mixed farmer under a cotton-based economy uses his F_3 land in periods 1, 2, 3 and 4 for grazing during the dry season, and uses part (20%) of F_2 land in periods 5 and 6 (planting time), plus part (3%) of F_5 land in periods 7 and 8 when the crops are growing in the fields. Then he uses again the F_3 land in period 9 after crop harvest. The medium-size farmer uses F_3 and part (32%) of F_2 land for grazing in periods 1 to 6 during the off-season, but he uses part (14%) of F_5 fallow land during the cropping season plus F_3 land and part (15%) of F_1 land in period 9, after harvesting. Thus, regardless of the farm size or whether the cash economy is cotton- or maize-based, farmers employ a similar pattern of grazing. During the dry season, animals are grazed on marginal lands, primarily F_3 and F_4 plus small parts of F_2 lands. During planting and the early cropping season, the animals are moved to land type F_2. Then at the height of the cropping season, animals are kept on the fallow lands (type F_5). So the pattern is to allocate more marginal land to grazing during the off-season and grazing on stubble for part of the cropland in period 9 after the harvesting of grain and crop residues.

Table 4 also shows the use of purchased inputs like chemical fertilizers N, P and K, plus hired labor, both of which interplay with the integration of crops and livestock. According to the fertilizer dosage in Northern Cameroon of 90-30-30 kg/ha for N, P and K, respectively, the purchases of the chemical fertilizers, for instance, by a small mixed farmer of 649.9 kg of compound NPK, 283.62 kg urea and 372.17 kg of superphosphate would be equivalent to 260.44 kg of N, 131.98 kg of P and 64.99 kg of K, which would just be enough to crop only 2.88 ha under maize and cotton. The small farmer, under a maize-based economy, would only be able to crop 2.8 ha instead of 7.23 ha (see Table 3). Similarly, the medium-size farmer would have cultivated less cropland with the purchases of fertilizers indicated in Table 4 under both cotton and maize-based economies. Table 4 also shows that a small mixed farmer under a maize-based system needs to hire 4.597 man-days labor or 3.81 man-hours/ha, but a medium-size farmer can hire 58.98 man-days of labor under a cotton-based or 145.168 man-days under a maize-based economy. This equates to just 6.49 days/ha or 12.54 days/ha which is quite reasonable compared to the farm size. These results, therefore, suggest that the integration of crop-livestock is not only complementary, but also saves on the purchases of fertilizer inputs and hired labor.

4.4 Disassociating Cotton With the Purchase of Fertilizers

One of the features of this model is a preharvest constraint whereby the sales of cotton limit purchases of chemical fertilizers, thus creating a cotton-based rural economy. With the available improved crop technologies and according to the results in Table 3, dissociating cotton from the purchase of chemical fertilizers results in a maize-based economy.

We shall now compare the gross margin under a cotton-based versus maize-based rural economy in Table 3. The maize-based economy increases the gross margin of small and medium-size farmers by 9 and 19%, respectively. It also increases that of the mixed farmers by 6.4 and 9.1%, respectively. The farm sizes are increased by 26.28% for the medium-size crop farmer and 27.34% for the medium-size mixed farmer, plus 3.42% for the small mixed farmer. As for the land allocation to various crops, maize takes on the largest part of land in each case. Under a maize-based economy the maize crop is regarded as both a food crop and an economic booster, so the cotton crop is dropped out by the model whether with or without livestock. Regarding land resource productivity, crop farmers under the maize economy may maintain land productivity at the same level as, for instance, with traditional crops, but triple their farm size, or the mixed farmers may raise their land productivity 6-10% less than that under the cotton-based economy, but double their farm size. This suggests that disassociating cotton with the purchase of fertilizers enables the farmers to operate a maize-based rural economy and increase their farm incomes by 3-27%.

4.5 Animal Feed Management Through the Dry Season

Among the livestock activities included in this model are constraints ensuring that sources of feed meet the animals' nutrient requirements in each time period. In each optimal solution, the model indicates quantities of crop residues and hay from grass that need to be fed to a specific number of animals by period in a balanced diet, as well as the grazing schedule to supplement stall feeding. The amounts of crop residues needed each year per type of farmer to feed his livestock are summarized in Table 4 and the land grazing schedule shown in Table 5. According to this model the mixed farmer has to harvest sufficient quantities of crop residues and hay (see Table 4) after crop harvest in period 9, then store these to be fed to the animals in later time periods. For example, a medium-size mixed farmer with 11 cows under a cotton-based economy, say in periods 1 and 2, can use as his source of animal feed, in kg per cow per day, 0.45 cowpea stalks, 4.237 maize stover, and 8.166 hay from grasses. This would be supplemented by grazing standing hay on F_3 and part of F_2 land. In periods 3 and 4, which is the height of the dry season, this farmer would have to increase his stall feeding rations since there is hardly any grass for grazing. Thus in period 3, the rations (kg per cow per day) would be 4.553 maize stover, 8.619 hay and 0.626 sorghum stover, while in period 4 the stall feeding ration (kg per cow per day) should be 3.352 maize stover, 8.695 hay and 0.547 cowpea residues as a rich source of crude protein, calcium, phosphorous, and vitamin A. In period 5, which is the time for land plowing operations, the medium-size mixed farmer may increase his leguminous cowpea residue source of animal feed to 1.691 kg per cow per day and maintain hay as a source of energy at 8.739 kg/cow/day. The most important stall feeding ration change is in June (period 6) when the animals are being used to plow, perform the first weeding, and ridge. During this period, the farmer should feed each cow in kg per day, 4.566 maize stover, 8.607 hay and 0.623 sorghum stover. Of course, in periods 7 to 9, which is the rainy season, the mixed farmer can stall feed supplemented by grazing on natural pastures, in periods 7 and 8, or on stubble in period 9, after harvesting the grain and crop residues. Similarly, the optimal solutions for the other categories of farmers specify the desirable quantities of crop residues and hay to maintain a given herd of livestock at the farm each year (see Tables 3 and 4).

5. CONCLUSIONS AND POLICY IMPLICATIONS

The major objective of paper is to demonstrate the profitability and sustainability of integrating livestock into the present crop-based farming system in Northern Cameroon. An integrated crop-livestock linear programming model has been used to maximize the farmer's goals of profit maximization subject to subsistence constraints.

In this paper we have considered the small and medium-size crop and/or mixed farmers in Northern Cameroon, reviewed their farm resource endowments (land, labor, farm cash and sources of animal feed) in contrast with their major production constraints of shortage of animal feed, labor bottlenecks, soil degradation and poor farm yields. It has been shown that by integrating crops and livestock into a single farming system, there are greater economic benefits and better use of intermediate farm resources such as animal manure, draught power and crop residues.

From these results, the following conclusions can be drawn:

1. The results indicate that improvements to the present farming system via the introduction of improved crop technologies and new varieties appear to produce only modest income gains (less than 20%). The income gains associated with the introduction and integration of livestock are quite large in contrast (nearly a four-fold increase for our small-scale farmer and almost a three-fold increase for the medium-size farmer).

2. In addition, if maize markets can be developed to the point that maize becomes an important cash crop, and maize farmers can get access to fertilizer supplies, then additional gains in the 5-20% range may be achieved.

3. The introduction of improved crop technologies alone, despite its moderate economic gains, is likely to require an increase in the importation of chemical fertilizers, and may not make efficient use of the low fertility fallow and/or marginal land as when combining with organic manure. That is, in the long run, farmers may still face a

severe soil fertility constraint. On the other hand, by adopting improved crop technologies together with the integration of crop-livestock, the gains should be sustainable through the efficient feeding and use of livestock by-products.

Animals are fed with a combination of grazing stubble and stall feeding of purchased feeds and stored crop residues. The cropping system benefits from the use of animals for draught power, and soil fertility is maintained through the application of animal manure supplemented by smaller amounts of chemical fertilizers. The challenge to the research and extension system will be to raise the level of farmers management skills, since only through good management will the system sustain itself.

From a policy perspective, the path to improving farmer incomes is clear. By introducing strong research and extension programs focused on the integration of livestock and cropping systems, substantial gains can be made toward developing a sustainable, more productive agricultural sector in Northern Cameroon. Additional gains may also be achieved via the development of markets for alternative crops, by increased access to improved maize and cowpea seeds, and by improving access to fertilizer. However, the largest gains by far appear to be from education of farmers regarding the necessary practices and benefits of an integrated crop/livestock production system.

NOTES

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TABLE 1. Cropping and livestock calendars in the crop-livestock integration model.

Cropping calendar				Livestock calendar		
Period	Days	Labor hours	Draught hours	Month	Period	Days
January 1-March 31*	28			January	1	31
				February	2	29
				March	3	31
April 1-30	5	82.5	12.5	April	4	30
May 1-15	13	215.5	32.5	May	5	31
May 16-31	13	214.5	32.5			
June 1-15	13	214.5	32.5	June	6	30
June 16-30	13	214.5	32.5			
July 1-15	13	214.5	32.5	July 1- August 31	7	62
July 16-31	14	231	35			

August 1-31	26	429	65			
September 1-October 31	53	874.5	132.5	September 1-October 31	8	61
November 1-December 31	49	808.5	122.5	November 1-December 31	9	61

*No labor constraint is needed because January to March is a dry season and a slack period for crop production activities.

TABLE 2. The gross margin, animals kept and crops grown by representative crop or mixed farmers in Northern Cameroon obtained from farm surveys and livestock-crop LP validation runs.

Item	Farm survey traditional crops				Validation from LP solutions with traditional crops			
	Crop farmer		Mixed farmer		Crop farmer		Mixed farmer	
Gross margin (U.S. dollars)	998		2678		1180		4887	
Livestock								
cattle	0		4		0		2	
goats	0		8		0		9	
Farm size, ha	2.553		5.14		3.401		7.3833	
Crops grown	ha	% of farm size	ha	% of farm size	ha	% of farm size	ha	% of farm size
Maize	0.583	0.228	0.713	0.139	1.1153	0.328	3.4922	0.4730

Groundnut	0.330	0.129	0.836	0.163	0.1629	0.048	0.6512	0.088
White sorghum	0.120	0.047	0.411	0.080	0.1110	0.033	0.1875	0.0254
Cowpeas	0.140	0.055	0.222	0.043	0.9000	0.265	0.7344	0.0995
Red sorghum	0.500	0.196	0.879	0.171	0.0799	0.024	0.1726	0.0234
Muskwari	0.600	0.235	0.614	0.120	0.7500	0.221	0.7500	0.1015
Cotton	0.280	0.110	1.465	0.285	0.2811	0.083	1.3954	0.1890

TABLE 3. Optimal solution of gross margin, livestock kept and crop area grown for a mixed or crop farmer with access to improved crop technologies in Northern Cameroon.

Item	Cotton-based				Maize-based			
	Without livestock		With livestock		Without livestock		With livestock	
	Small farmer	Medium-size farmer	Small farmer	Medium-size farmer	Small farmer	Medium-size farmer	Small farmer	Medium-size farmer
Gross margin in U.S. dollars	1368	2608	5226	7299	1490	3095	5563	7965
Livestock								
Cattle	0	0	2	11	0	0	2	5
Goats	0	0	1	0	0	0	2	4
Farm size, ha	3.878	7.336	6.991	9.088	3.781	9.264	7.23	11.573

Crops grown, ha								
Maize	0.8357	2.8921	2.55	4.7337	0.671	5.3145	3.2044	8.3
Groundnut	1.0	1.0	0.5653	0.6773	1.299	0.8646	0.6519	0.08
White sorghum	0.0811	0.366	1.3733	0.6886	0.0811	1.3412	1.6299	1.4491
Cowpeas	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Red sorghum	0.0799	0.094	0.094	0.094	0.0799	0.094	0.94	0.094
Muskwari	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Cotton	0.2315	1.3342	0.7541	1.2408	0	0	0	0

TABLE 4. The optimal use of intermediate farm products, resources and purchase inputs by a mixed farmer in Northern Cameroon.

Item	Cotton-based		Maize-based	
	Small farmer	Medium-size farmer	Small farmer	Medium-size farmer
Animal feed used (m.t./yr)				
Groundnut residues (dry)	1.978	2.371	2.281	0.28
Sorghum stover (dry)	2.226	1.193	2.605	2.333
Cowpea residues (dry)	2.7	2.7	2.7	2.7
Maize stover (dry)	12.749	23.669	16.024	41.53
Hay from grasses	4.625	17.187	6.061	32.119
Use of owned draught:				
Plowing (hrs)	168.44	228.02	175.82	286.41
Weeding + ridging (hrs)	121.11	187.58	120.75	260.18
Transportation (hrs)	77.11	95.93	78.87	109.92
Animal manure (m.t./year)	4.03	19.8	4.46	10.23
Cropland from fallow				
Convert F_5 to F_1	0.1942	2.8646	0.0944	5.19
Convert F_5 to F_2	0.5766	0	0.9158	0.1632

Purchased fertilizers (kg)				
Compound NPK	649.9	609.4763	645.29	2182.23
Urea	283.62	613.8794	267.66	1233.95
Superphosphate	372.17	946.124	386.12	972.96
Hired labor, man-days	0	58.98	4.597	145.168

TABLE 5. Land schedule in hectares for grazing animals in a crop-livestock integration model of Northern Cameroon.

Farmer		Land type	Livestock calendar								
			1	2	3	4	5	6	7	8	9
Cotton based	Small	1									
		2					.2893 (20%)	.2893 (20%)			
		3	.9 (100%)	.9 (100%)	.2893 (32%)	.2893 (32%)					.2893 (32%)
		4									
		5							.2893 (3%)	.289 (3%)	
	Medium	1									0.464 (15%)
		2	.464 (32%)	.464 (32%)	.464 (32%)	.464 (32%)	.6886 (47%)	.6886 (47%)			.9 (100%)
		3	.9 (100%)	.9 (100%)	.9 (100%)	.9 (100%)	.6754 (75%)	.6754 (75%)			
		4									
		5							1.364 (14%)	1.364 (14%)	

Maize based	Small	1									
		2									
		3	.2996 (33%)	.2996 (33%)			.2996 (33%)	.2996 (33%)			.2996 (33%)
		4			.296 (40%)	.2996 (40%)					
		5							.2996 (3%)	.2996 (3%)	
	Medium	1									
		2					1.449 (99%)	1.449 (99%)			
		3	.7173 (80%)	.7173 (80%)							.7173 (80%)
		4			.7173 (96%)	.7173 (96%)					
		5							.7173 (7%)	.7173 (7%)	
Crop season			Dry and hot season				Planting	Cropping + harvesting			Post-harvest